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ANNUAL REPORT, 1980.(U)
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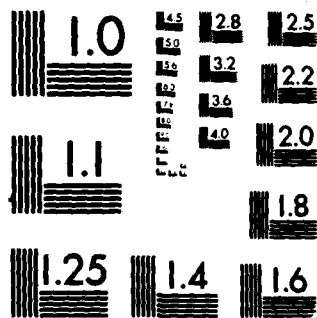
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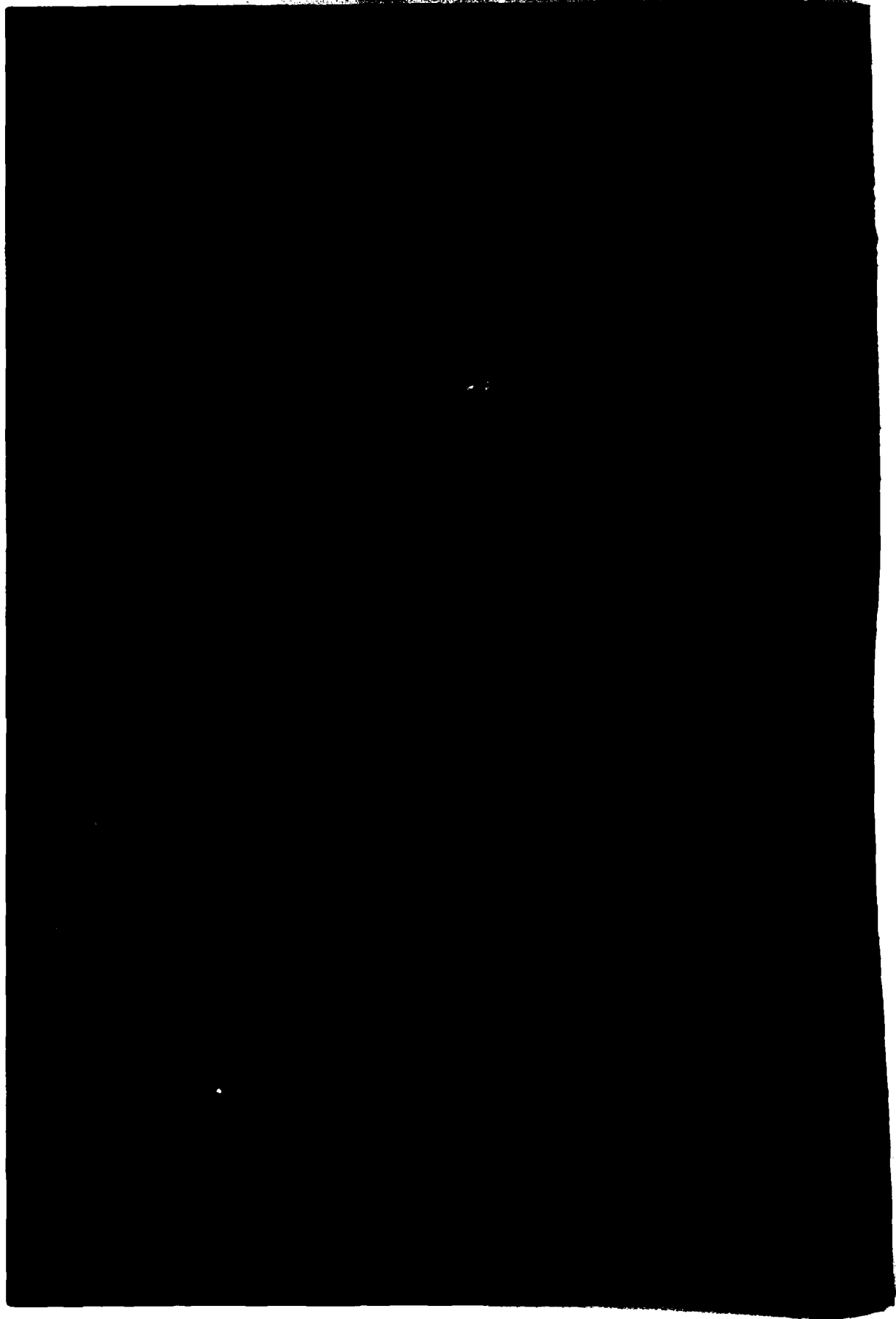
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30 JAN 1981

From: Chief of Naval Operations
To: Distribution List

Subj: 1980 Annual Report of the Center for Naval Analyses

Encl: (1) Subject Report

1. Every year a Board of Overseers reviews the work of the Center for Naval Analyses. This year's report (enclosure (1)) reviews CNA's research and use of Government resources from 1 October 1979 through 30 September 1980.

2. The report also includes a discussion of the special attributes of continuity, independence, pertinence, and quality that characterize CNA and its research. The description of CNA's unique character indicates why the Center continues to make an important contribution to the nation's defense.

3. The Navy and Marine Corps are well served by CNA.

A handwritten signature in dark ink, appearing to read "J. S. Bolcomb".

J. S. BOLCOMB
Director
Naval Planning

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 26KK Tactical Training Group
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 28B Cruiser-Destroyer Group
 28C1 Surface Group LANT
 28C2 Surface Group & Force Representative PAC (COMNAV SURF-
 GRU1DPAC and COMNAV SURFGRUWESTPAC only)
 28D Destroyer Squadron
 28K Submarine Group and Squadron
 28L Amphibious Squadron
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 Development Squadron (VXM) (VX-1, VX-4, VX-5 only)
 42X Fleet Air Reconnaissance Squadron

42AA2

Fleet Intelligence Support Center PAC

45A2

Marine Amphibious Force

45B

Marine Division

45Q

Division and Service Support Group and Battalion
 (FIRST FSSG, CG SECOND FSSG, THIRD FSSG only)

45V

Brigade and Amphibious Unit (CG FIRST MARBDE only)

46B

Aircraft Wing

50A

Unified Commands

50B

Specified Commands

51A

Supreme NATO Commands

51B3

Southern Europe Area (CINCSOUTH only)

C4F61

Field Operational Intelligence Office Branch
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C37A2

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FKA6A

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FKP1G

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FKR3C

FKR3E

FKR4A

FRS5
FKR7E
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THE CENTER FOR NAVAL ANALYSES
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FOREWORD

Five years ago, the annual report of CNA was redesigned to be more informative to those not already familiar with the Center's purposes and accomplishments. Every report since has devoted one section to one or another of the traits that make CNA *the* source of independent and informed analysis for the Navy and Marine Corps.

The first section of this report draws together the main themes of the earlier reports to show why CNA is, as a former Assistant Secretary of the Navy once said,

close enough to the Navy so that it understands what is going on . . .
but is ornery enough that it will answer back, and independent
enough that it will give an answer which has nothing to do with what
it thinks the Navy might want the answer to be.

Because of CNA's status as a non-profit affiliate of the University of Rochester, the test of its worth is not its balance sheet but, rather,

the pertinence and quality of its research. Each annual report therefore pays special attention to examples of CNA's research accomplishments. More than twenty studies are summarized in the second section of this report.

The summaries attest not only to the pertinence and quality of CNA's research, but also to its continuity and coherence. These characteristics are made possible by the close and stable relationship between the Center and the Navy and Marine Corps.

As in past years, we also describe the way CNA is organized, present the credentials of its staff, account for the funds entrusted to it, and state the membership of the Center's Board of Overseers.

In last year's report we noted the merger of the Systems Evaluation Group into the Naval Warfare Analysis Group (NAVWAG). Robert Corn became director of the larger NAVWAG after having served since 1976 as director of the Marine Corps Operations Analysis Group (MCOAG); Dorothy Yufer joined CNA's management staff in 1980, as deputy director of NAVWAG. Mrs. Yufer has served as a deputy in the Directorate for Test and Evaluation of the Office of the Secretary of Defense. Dr. Corn's successor as director of MCOAG is Christopher Jehn, who brings to that group his experience as director of CNA's Institute of Naval Studies (INS). Stanley A. Horowitz a ten-year member of the INS professional staff, was appointed to direct INS.

With confidence in the future of CNA and its service to the Navy, Marine Corps, and nation, we submit this report.


David Kassing
President


W. Allen Wallis
Chairman of the Board

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I. THE CHARACTER OF CNA

The nation's maritime forces — the Navy and Marine Corps — are equipped, manned, trained, and kept in readiness at an annual cost of some \$50 billion. In today's world, even this much money cannot guarantee the naval superiority of the United States. The uniformed leaders of the two services therefore look to quantitative analysis for help in making present forces more effective and shaping the forces of the future.

The Navy pioneered in the application of quantitative analysis to U.S. military problems when it formed the Anti-Submarine Warfare Operations Research Group (ASWORG) in 1942. Today, both the Navy and the Marine Corps rely on the Center for Naval Analyses — a lineal descendant of the ASWORG — to supply analytical expertise not available within the services.

The unique and long-standing relationship of the Center to the Navy and Marine Corps gives it the freedom and knowledge to anticipate problems and analyze potential solutions, even before the problems become urgent. At the same time, CNA can attack more immediate problems with an authority born of its depth of experience in naval matters.

This portion of the 1980 Annual Report describes the traits of continuity, independence, pertinence, and quality that make CNA the Center for Naval Analyses, in more than name.

CONTINUITY

For 38 years, CNA and its antecedents have served the Navy's analytic needs; service to the Marine Corps has continued for 23 years. And in those years — through war and peace, through periods of rapid growth, and through transfers of sponsorship — change has been gradual in the staff of the Center. Each new generation of analysts has had ample time to learn from those who came before, thus creating a fund of collective understanding of naval and amphibious warfare. At the same time, the steady infusion of younger members has advanced CNA's collective knowledge of analytic techniques.

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This process of intellectual growth is nurtured by CNA's status as a Federal Contract Research Center (FCRC). FCRCs are non-profit, are generally funded by sole-source contracts, and exist primarily to work for the Department of Defense, though they do a limited amount of research for non-defense agencies of government. They have privileged access to information and the expectation of reasonable stability and continuing support from their sponsors.

Through this stable and continuing relationship, CNA has not only developed an expert staff but has also acquired and developed collections of data, models, and analytical and technical reports pertaining to naval subjects that are without equal in the analytical community and, in some instances, the Navy Department.

These collections do not lie fallow. For example, today's models of antisubmarine warfare owe much to those developed in World War II; present models of aircraft carrier operations evolved from work during the Korean War; today's methods of analyzing aerial combat build upon analysis done in the Vietnam War.

Continuity of clientele, of staff, and of information are signs of professionalism, but they do not guarantee it. Professionalism also requires independence — the willingness and ability to diagnose a client's problems freely and to prescribe solutions, whether they are palatable or not.

INDEPENDENCE

CNA has great latitude in shaping its annual program of studies. CNA, alone, directs the course of each study. And, regardless of where a study may lead, CNA is free to publish its results.

The agreement between the University of Rochester and the Navy Department requires the CNA management and the Navy to "formulate an annual CNA study plan, addressing the work to be done and the allocation of CNA resources." Moreover, "once this study program for the year is underway it should not be changed in any major way" without agreement. The stability inherent in an annual program protects the organization's resources against excessive diversion to day-to-day problems.

1. The Character of CNA / 3

CNA's work for the Navy's operating commands must, however, be more flexible than is possible in an annual program. Operations often give rise to issues that must be resolved quickly. Even in this work, however, CNA and the Navy see to it that analysts are so allocated among the operating commands as to focus analytical help where the fleet needs it most.

CNA's work for the Marine Corps combines headquarters studies and field work. The program of studies is prepared jointly with the headquarters staff every six months; field assignments are reviewed annually.

The process of constructing the formal study program has three distinct steps: listing possible projects, preparing a tentative program, and agreeing on a definite program.

In the first step, members of the CNA staff suggest topics for study, many of which are based on discussions with Navy and Marine Corps personnel in Washington and the field. In addition, members of the CNA management visit most of the senior staff officers of the Office of the Chief of Naval Operations and of Headquarters, Marine Corps, to solicit ideas. For an outside view, CNA managers also meet with the staffs of the National Security Council and the Office of the Secretary of Defense, as well as other members of the analytical community. Meanwhile, the Navy and Marine Corps are preparing their own lists of candidate research subjects for CNA. The combined list — even after duplicates are eliminated — represents much more research than CNA can possibly conduct. Choices must be made, priorities set.

The second step, then, is for CNA's managers to prepare a proposed program of research that draws from the combined list. They choose the subjects that in their judgment are of the most importance to the Navy and Marine Corps, with emphasis on:

- Problems that involve many parts of the Navy and Marine Corps, or significant shares of their budgets, so as to "leverage" the analytical skills of the CNA staff.

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- Projects involving a significant element of uncertainty and risk of failure, where the first task is often to define the problem at hand — not projects requiring only the routine application of existing research tools.
- Projects that require the intellectual talents of the CNA staff and will both draw and build upon its experience.
- Problems that by their nature pose a challenge to vested interests or to “conventional wisdom” and therefore require an independent and innovative point of view.

The final step is agreeing on a program with the Navy Department. More often than not, there is close agreement between the program proposed for CNA by the Navy Department and the one selected by CNA's management. But close agreement is not always full agreement. Some study proposals must be reconsidered by both the services and CNA. Reconsideration leads eventually to an agreement between CNA and the services.

Total agreement is not essential. If the Navy or Marine Corps believes that a specific study should not be done but CNA thinks it should, the study can be carried out as a CNA-initiated project. CNA can thus start work on potentially important analyses before the issues become pressing problems for the services, or can study new applications of academic disciplines to naval problems, or can conduct research whose outcome is especially uncertain. CNA-initiated projects may absorb up to 23 percent of the funds provided under the agreement between the Navy Department and the University of Rochester, though such efforts seldom require more than 10 percent of the funds.

The final program is designed to allow change; that is, some studies are scheduled to end while others have yet to begin. This staggered schedule permits CNA to take on short, urgent studies that could not be anticipated when the formal program was being constructed — and to do so without interrupting research already in progress. Sometimes, however, the Navy or Marine Corps does ask CNA to interrupt a research project in favor of a short-term study of a pressing issue. CNA considers such requests carefully, rejecting those to which it could not make an adequate contribution or which would unduly

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disrupt long-term research; this right of rejection is guaranteed in CNA's basic contract. Conducting a limited number of short-term analyses enhances CNA's effectiveness and sharpens its understanding of issues, to the benefit of later research.

Short-term or long-term, self-initiated or not, CNA studies are conducted under the direction of the President of CNA, not the Navy or Marine Corps. The services cannot halt a study, even if it begins to show results unfavorable to a service position. The agreement between the Navy Department and the University of Rochester requires the concurrence of CNA in the cancellation of any study.

Nor can the Navy or Marine Corps suppress the final report of a study. The agreed-upon distribution list includes about 75 addressees outside the Navy Department, including the Secretary of Defense, the Joint Chiefs of Staff, the other services, the Central Intelligence Agency, the State Department, and the other Federal Contract Research Centers. The Navy and Marine Corps — and the CNA management — know that any one of these organizations would be quick to point out biased analysis or unsupported conclusions.

CNA's independence of view is further assured by the fact that the Navy and Marine Corps are not monolithic. Challenges to vested interests and "conventional wisdom" arise from within, as policies and programs are shaped. The Center's role is to aid the shaping process — to help in defining and weighing competing views. Even if a CNA study is subsequently cited to support a chosen policy or program, intraservice proponents of different choices will have scrutinized the study. They, too, would be quick to point out biased analysis and unsupported conclusions.

PERTINENCE

The relative independence that CNA enjoys in formulating and carrying out its study program would count for little were its management and staff to act on secondhand knowledge of the Navy, the Marine Corps, and their problems. A close, working knowledge of the services, access to data, and frequent exchanges with senior Navy and Marine Corps officers ensure a pertinent study program and

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studies that faithfully represent the realities of naval and amphibious warfare.

CNA's knowledge of Navy and Marine Corps operations is founded on its field program. At the end of 1980, CNA had 38 analysts — nearly a fourth of its professional staff — at Navy and Marine Corps commands, from the western Pacific to the central Mediterranean, working closely with staff officers on problems of immediate concern to the fleet. In a tour of one or two years at a field command, a CNA analyst has enough time to understand the systems and operations he or she is to analyze and to balance the many requests for analysis that they receive.

The data collected and analyses done in the field are also important to CNA's formal study program. They form the basis for realistic estimates of how well present and future weapon systems may be expected to perform in combat. They suggest alternatives worth the attention of the Navy and Marine Corps. Returning field representatives are often able to follow up such questions at CNA-Washington. There they may work with teams of specialists in a specific warfare area or with interdisciplinary study teams examining a range of possible force structures.

Though many studies at CNA-Washington rely on data collected in the field, many more require data that can be obtained only through the Navy and Marine Corps. CNA's access to such data is guaranteed, within the limits of security, by the agreement between the Navy Department and the University of Rochester.

At CNA-Washington, as in the field, contact between the CNA staff and the Navy and Marine Corps is part of the job. For example:

- Senior managers attend meetings of the Executive Board of the Chief of Naval Operations, where major policy decisions are discussed.
- All CNA managers meet frequently with senior officials involved in — or in charge of — analysis, force and manpower planning, weapons acquisition, and logistic support activities for the Chief of Naval Operations and the Commandant of the Marine Corps.

I. The Character of CNA / 7

- Each CNA study is monitored by an advisory committee, usually chaired by an admiral or general. In the course of the study, the advisory committee is briefed on the study's progress and results.
- CNA analysts meet often with the staffs of advisory committee members to obtain data, explain methods of analysis, and discuss the pertinence of the methods.
- Study results are often briefed to the service chiefs and to the Secretary of the Navy – and sometimes to senior officials in the Office of the Secretary of Defense.

These contacts are an important means by which CNA learns of its clients' analytical needs. At the same time, CNA's clients are able to learn more of the details of the research they have sponsored – and to express their opinions of the research. Though CNA welcomes these expressions of view and benefits from them, it is up to CNA to decide what to do about them.

A special feature of the Navy-CNA relationship is the assignment of Naval officers to CNA as analysts (see "Research Support Activities – Operations Study Group" in section III). About 25 officers are thus assigned; most hold postgraduate degrees, and all have had duty in the fleet. As analysts, the officers carry their share of the workload; as officers, they are quick to point out when analysis strays from the realities of naval warfare. While assigned to CNA, these officers work under the direction of the President of CNA.

Though an understanding of the Navy and Marine Corps and of the problems they face is essential if CNA is to do pertinent research, the proof of pertinence is in the research itself. Section II of this report discusses examples of CNA's research in 1980; earlier annual reports summarize dozens of other projects. The record speaks for itself.

QUALITY

The quality of analysis in a research organization depends – first of all – on the quality of its staff. Research tools, such as computers, foster efficiency, but human intelligence must guide their use. As a

8 / 1. The Character of CNA

part of the University of Rochester, CNA can attract top-quality analysts and leaders who might be reluctant to devote themselves to defense analysis under other conditions. Because CNA is not-for-profit and enjoys a stable, continuing relationship with its clients, the organization can choose and retain its staff members on the basis of their research qualifications alone. As a result, the CNA staff is exceptional in education and experience (see "Staff Composition" in section IV).

In addition to attracting dedicated and talented analysts, the University takes an active role in assuring the quality of CNA's research. Eight senior members of the University management are members of the Board of Overseers, which meets with CNA staff members three times a year to review their work (see section VI).

Other means by which CNA promotes the quality of its staff, its research, and its reports include:

- A continuing series of lectures that introduce new staff members to the Navy and Marine Corps, their analytical needs, and special techniques of analysis.
- Guest lectures by eminent practitioners of defense analysis and scholars in related academic disciplines.
- Reimbursement of expenses for graduate-level courses in subjects related to CNA's research.
- A staff of six professional editors and — new in 1980 — a course in writing.

A cornerstone of quality at CNA is its formal and rigorous review process — perhaps unique among analytical organizations — which begins long before a final report is drafted and culminates in a detailed, written critique of the draft.

To help put a study on track in the first place, there is a "prenatal" review. In-process reviews keep it on track.

As the name implies, the "prenatal" review is held before a study has really begun. The purpose is to reach agreement on the issues that

will shape the future of the study — the proposed method of analysis, sources of data, important assumptions to be made, assignment of personnel, scheduling, and — always the most important and often the most difficult — precisely what the question is that the study will try to answer. Deliberations on these matters involve CNA's senior managers and the director of the research group that will conduct the study, as well as the members of the study team.

At in-process reviews, the same members of CNA take part. The study team describes progress made and problems that have arisen. The purpose is to uncover weaknesses in the analysis, suggest improvements, resolve problems, and when necessary, revise the approach to the study. The number of in-process reviews depends on how hard the study turns out to be, and how long it takes.

It is not until there is a draft of the study's report that the Director of Program Review and his staff make their detailed review. This is CNA's most meticulous, time-consuming review.

The reviewers look for many things: The assumptions underlying the analysis must be appropriate, the analytical method must fit the problem, mathematical expressions must be derived correctly, statistical inferences must be valid, the arithmetic must be accurate. What is said in one part of a report must not conflict with what is said in another. A reviewer is also concerned with whether the analysis is properly documented, the sources of data and methodology are properly referenced, and the work is reproducible; that is, whether another analyst, applying the method of the study, will get the same results.

But the best analysis in the world is useless if the report is unclear, misleading, unpersuasive, overlong, or convoluted. These are matters of presentation, and CNA places great emphasis on good exposition. CNA reviewers therefore criticize presentation as well as analysis.

Critiques are written. The reviewer and research manager have an opportunity to weigh the consistency, accuracy, and value of the criticisms. A written review also gives the research manager explicit comments to act on — or to refute if he does not agree with them. Moreover, CNA's President and Executive Vice President — who see

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all review memoranda — are given another way to judge the work of the study team. In addition to detailing any weaknesses a reviewer may have found, a review memorandum also suggests specific ways of improving the report or, if need be, the analysis underlying it.

The formal review process is intended to assure the quality of specific research. A generally high level of quality also demands a certain amount of self-questioning: Is CNA overlooking important areas of inquiry? Is its research aimed at less important problems than it should be? Are methods of research, rather than problems, driving the study program? Such issues are frequently discussed at the weekly meetings of the CNA management and are the focus of annual reviews of goals, programs, and progress.

Self-questioning has even led to a CNA-initiated study of the completeness and competence of an earlier, large-scale analysis of a naval campaign set in the future (see "Methods of Military Operations Research — A Campaign Analysis Revisited" in section II). This "analysis of analysis" influenced the internal debate over inferences to be drawn from a new campaign study being completed about the same time. As a result, CNA management redoubled its scrutiny of the results of the new campaign study and reshaped its conclusions and recommendations.

The competence of CNA's research, then, is more than the product of a competent staff and a rigorous program of quality control. To these essential attributes, CNA adds the academic traditions of tough questioning and open debate, as befits a university affiliate.

II. 1980 RESULTS

The examples in this section represent only about a fourth of CNA's research during FY 1980. Classified details have, of course, been excluded. Nevertheless, these brief descriptions give something of the flavor of CNA research in the past year. The research outlined here is reported in detail in CNA publications. The classified publications are available to qualified recipients.

These are the subjects covered:

Current Operations

- War in the Dark
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These examples are followed by titles of unclassified research projects conducted at the University of Rochester under the CNA contract.

CURRENT OPERATIONS

War in the Dark

Even in this age of technical sophistication, the darkness of nighttime is still a major factor in warfare. The advent of radar more than 40 years ago did not entirely surmount the difficulty of finding a target at night and identifying it as enemy, friend, or neutral. The problems of nighttime warfare are especially troublesome to naval aviators. CNA has helped the Navy apply new technology to these problems.

Until quite recently, distinguishing friend from foe after sundown — when neither is using radio or radar — was done in the same way as in World War II: Find a target with your radar, fly close, illuminate it with a flare, and look at it. The lethality of today's radar-directed guns and surface-to-air missiles makes this tactic very dangerous. But there are now Forward Looking Infrared (FLIR) systems, which turn night into day. These systems are to be fitted into the Navy's A-7E light attack aircraft and A-6E medium attack aircraft.

A user of the system must be able to predict the range at which a FLIR detection will occur. That range depends on the characteristics of the target (e.g., how hot it is relative to the background), atmospheric conditions, and the characteristics of the FLIR device itself. Knowledge of the detection range is important because it strongly influences the choice of tactics.

Available models for predicting detection range were either too complex for shipboard use, too detailed, or too limited. A CNA analyst worked with the first A-7E squadron equipped with FLIR to develop a useful model. The work was done during the training period before the squadron's deployment overseas and during its transit back to the U.S.

Though not enough data were collected during the training period and cruise to validate the model developed by CNA, the data did confirm the prediction that altitude would have a considerable effect on detection range. CNA has helped collect and analyze data from subsequent operations by aircraft equipped with FLIR. These data are being used both to validate the present CNA model for predicting detection range and to develop others.

Performance of Antisubmarine Warfare Aircraft

The S-3A is a carrier-based aircraft designed primarily for antisubmarine warfare (ASW); its land-based counterpart is the P-3C. Both are major elements of the Navy's ASW forces, and CNA assigns a high priority to improving their performance.

Because the S-3A has also been used for a variety of other tasks related to the operations of a carrier battle group, the Department of Defense has been concerned about the effectiveness of the aircraft in its ASW role.

To meet this concern, the Navy has been assessing S-3A performance, with emphasis on ASW, and has gathered data on the aircraft's ASW effectiveness from messages prepared by aircrews at the end of each mission. The messages describe various aspects of the mission: when, where, and why it was flown; the prevailing weather conditions and acoustic environment; and the techniques used to detect and attack a submarine.

CNA has helped in the assessment by analyzing messages transmitted during major ASW exercises. The analyst involved in these efforts also spent five weeks aboard the aircraft carrier John F. Kennedy, gathering data on the performance of the S-3A during the evaluation of the carrier airwing's training and operational readiness.

One purpose of the analysis was to develop ways to evaluate S-3A performance from data collected at sea, rather than on an instrumented range. The analysis has concentrated on providing force commanders with information about aircraft use, particularly in ASW. CNA has also helped to develop message formats that increase the amount of data available for further analysis by computers.

Another CNA analyst evaluated the ability of the Pacific Fleet to use the P-3C to protect carrier battle groups operating in the northwest Pacific Ocean. Such ASW protection is vital to the Pacific command's strategy of "prompt offensive action."

The analyst looked into the effectiveness of the aircraft assigned to protect battle groups and the adequacy of the numbers of aircrews available to fly the missions. Mathematical models were used to

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estimate the effectiveness of ASW screens while a battle group is in transit and of fixed barriers while a battle group remains in one place to conduct air strikes.

The analysis gave the Commander-in-Chief of the Pacific Fleet a realistic estimate of the protection that P-3C aircraft can lend to his battle groups and of the number of fully manned and trained aircrews required. The analysis also pointed to logistical problems that could limit the ability of the P-3C to protect battle groups.

Fleet Anti-air Warfare (AAW)

This continuing project seeks to improve the AAW effectiveness of the fleet by seeking out deficiencies in tactics and systems and recommending improvements.

One important aspect of AAW is the outer air battle, in which carrier-based fighter aircraft engage enemy bombers. Of primary concern is the ability of the fighters to attack the bombers before they can launch their cruise missiles. Successful defense depends on detection, command and control, and tactics.

CNA developed a model to calculate the probability that an F-14 pilot will detect an incoming bomber in the sector assigned him. The racetrack pattern followed by the patrolling F-14 was found to reduce substantially the chance that an enemy bomber will get through to the U.S. force. CNA also studied the degree to which jamming reduces the ability of the E-2C early warning aircraft to detect enemy bombers.

Results of CNA research into command and control suggest that aircraft have so little time to respond to a threat that a centralized command authority may be unable to exercise effective control. The problem may be eased if AAW aircraft are provided with preplanned responses to the various situations that may arise.

The study team is also looking into the effective use of radar by the ships of a battle group. For defense against air attack, a battle group employs a mixture of weapon systems. To use them successfully, the commander must have a clear, current picture of what is happening. This picture is provided almost entirely by radar.

The latest improvement in shipborne radar is automatic detection and tracking (ADT). In an ADT radar, detection and tracking — previously performed by people — are taken over by a computer. This change ensures faster and more accurate tracking of today's antiship missiles, which fly much faster and higher than those of the past.

In 1980, when the Navy introduced the ADT radar (SPS-48C), CNA analysts collected data on its performance. Then, applying methods of reconstruction developed at CNA, the analysts picked out the real aircraft tracks, determined their duration, and pieced together a clear picture of how well ADT was working.

The analysts found several problems that were attributable to either the ADT's computer programs or its interface with the ship's tactical data system computer. Improvements proposed by CNA were evaluated at sea and later adopted on all ships equipped with the SPS-48C.

New Tactics for Submarines

The Navy is assessing the new 688-class nuclear submarine (SSN 688) and developing tactics to make it as effective as possible. CNA analysts have taken part in planning, conducting, and analyzing operations to test the submarine and have evaluated its ability to detect, identify, and attack both nuclear- and diesel-powered submarines. Their analysis has shown significant tactical advantages of the SSN 688 over earlier classes of submarines.

CNA has also developed simpler ways to reconstruct and analyze submarine exercises. These methods have been applied in tests of the effectiveness of a nuclear submarine against a diesel-electric submarine.

CNA analysts have devised techniques by which a submarine crew can improve mission planning. They have also developed new ways for the crew to analyze the movements of its target and have evaluated new methods of determining range to target by information obtained at the time of detection.

FUTURE MISSIONS AND FORCES

Evolution of Soviet Military Doctrine

CNA's specialists in Soviet affairs have traced the evolution of Soviet strategy from 1960 and have identified the likely course of this evolution beyond 1980. Their analysis draws on statements in the military literature of the Soviet Union and correlates them with what is known of Soviet force capabilities through operations and exercises.

The timing of major changes in Soviet military doctrine suggests that these changes coincide with the USSR's five-year plans. The evident objective is the addition of a new military option in each five-year period.

In the first half of the 1960s, Moscow apparently felt it had only one practical strategy — all-out nuclear war. At the turn of 1965-66, another possibility — conventional local war — was added to underpin a diplomacy of force in the Third World. At the turn of 1970-71, Soviet statements began to point to a policy of limited inter-continental nuclear war, initial counterforce strikes by land-based ballistic missiles, and the withholding of submarine-launched ballistic missiles. Finally, at the turn of 1975-76, evidence began to accumulate of a policy of counterforce strikes limited to targets in Europe.

Apparently, the long-term objective of more recent policies is development of forces that can win limited conflicts so that the Soviets will not be forced to choose between massive nuclear exchange and capitulation. The next Soviet steps may therefore be to develop doctrines and forces for sustained operations in tactical-nuclear war and conventional war.

Choosing the Next Attack Submarine

Though most of the 688-class submarines that have been authorized have yet to be delivered, the next generation of attack submarines is already being planned. Designs being considered in early 1980 as follow-ons to the 688 ranged from improved versions of the 688 to completely new designs. They differed in cost and in such operational characteristics as size, speed, and the number of weapons they could

carry. The problem was to decide whether the additional operational capabilities proposed were worth the additional cost.

CNA was asked to take on the problem. The CNA study group compared equal-cost forces of the candidate submarines for effectiveness in a non-nuclear war with the Soviet Union in the year 2000. The study group found that equal-cost forces of the candidates do about equal amounts of damage to the enemy in missions that do not require the expenditure of many weapons. In missions that do involve high rates of weapon expenditure, the new designs are more cost-effective than the 688. The faster the candidate, the more likely it is to survive attacks by submarine, air, and surface forces.

These findings are based on comparisons involving over 100 combinations of assumptions about scenarios, costs, threats, and operational characteristics. The results are helping the Navy to develop an acquisition and development plan for the next generation of attack submarines.

What Should Tomorrow's Warships Look Like?

The Navy asked CNA to help define the characteristics of a new class of destroyers, the DDGX, which is to start replacing older destroyers and cruisers in the late 1980s. The characteristics of the DDGX must therefore be determined very soon. Accordingly, CNA assigned the study a high priority and completed it in four months.

The analysis was performed in three stages. First was a qualitative analysis to define the kinds of missions to be carried out by the DDGX. The capabilities of the various kinds of forces with which the DDGX will operate were measured against the likely threat. Complementary capabilities needed by the DDGX were thus identified. All planned employments of the DDGX were considered, including operations with battle groups, surface action groups, underway replenishment groups, and amphibious task groups.

The study team then calculated the degree to which the effectiveness of each force group would change as a result of variations in the weapon mix carried by the DDGX. This stage of the analysis enabled the Navy to make more specific judgments about the contributions of the DDGX to the missions identified in the first stage.

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In the third stage of the analysis, the study group defined several DDGX designs (each with a weapon suite tailored to specific missions), estimated their cost, and constructed alternative force mixes. This information should help Navy decision-makers to choose between a single type of DDGX and a number of more specialized ships.

Carriers and Carrier-Based Aircraft of the Future

The Navy must also decide on a new generation of sea-based aircraft and carriers. Vertical/short takeoff and landing (V/STOL) aircraft offer several advantages over conventional takeoff and landing (CTOL) aircraft: They take less time to launch and recover, they can operate more readily from damaged ships, and they can operate from ships much smaller than today's carriers. With a larger number of smaller carriers, the Navy could disperse its airpower more widely.

For the past three years, CNA analysts have been conducting a series of studies to illuminate the choices between V/STOL and CTOL aircraft and among carriers of various sizes. Two of these studies were completed in 1980. One examined the issue of aircraft design in detail; the other was concerned with carrier size. In both cases, the analysts began by estimating the life-cycle costs of a variety of carriers and sea-based aircraft that could be part of a carrier force in the year 2000. Next, they developed equal-cost mixes of carriers and aircraft. Finally, they compared these mixes for effectiveness in several different scenarios.

The findings concerning aircraft design are inconclusive. V/STOLs are more effective in some situations, CTOLs in others. Findings about the carriers, however, are more clear-cut: Large carriers were found to be more effective, dollar for dollar, than smaller carriers.

Making the Marines More Mobile

In August 1979, the Secretary of Defense proposed several measures to speed the movement of Marine Corps forces to an area of crisis or conflict: Aircraft would fly troops to the area; their equipment and supplies would be delivered by ships deployed in forward areas for such contingencies. The method was to be followed only if the air and sea lifts were unopposed.

Both the Navy and the Marine Corps asked CNA to work out the details of the concept, check it for operational and technical feasibility, and estimate the cost of putting it into effect. To help the services decide quickly about budget allocations, CNA assigned a high priority to the study. It was completed in three months.

CNA's analysis showed that, despite many operational and technical problems that are yet to be overcome, the concept has no fatal flaw: Marines can respond much faster this way than if they are deployed by amphibious ships. The estimated costs of ships and equipment were within the guidelines set by the Secretary of Defense. Finally, the required airlift and flight-ferry operations are practical. The study group concluded that the concept provides the National Command Authority with a valuable new mobility option.

Based in part on CNA's analysis, Department of Defense officials made changes in the defense budget to allow immediate purchases of equipment. Until ships tailored to the Rapid Deployment Force have been constructed, the force must rely on existing ships. The mix of ships chosen is along lines suggested by CNA. The ships were loaded with supplies and equipment and sent to the Indian Ocean in July 1980.

New Combat Vehicles for the Marines

CNA evaluated a number of foreign vehicles being considered for the Marine Corps' Mobile Protected Weapons System (MPWS), which is essentially a light tank that can be carried by helicopter. The purpose of the MPWS is to make assault troops less vulnerable and to give them fire support before tanks and artillery are brought ashore.

Congress has asked the Marine Corps to assess off-the-shelf candidates for the MPWS — in particular, vehicles of foreign manufacture. Because of CNA's earlier analysis of the MPWS, the Marine Corps asked CNA to conduct the assessment.

The study team examined equal-cost forces of candidate systems. These included all currently available, lightly armored systems from abroad, as well as notional hybrids composed of various combinations of guns, turrets, and chassis. In all, 42 candidates were evaluated.

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The combat effectiveness of each vehicle was measured, in part, by mathematical models of duels between the MPWS and Soviet tanks and armored personnel carriers. The models computed the number of enemy targets killed by an MPWS before the MPWS itself was killed. Two additional measures were applied: vehicle mobility and transportability by the CH-53E helicopter.

Before the study had been completed, events abroad focused attention on the need for a Rapid Deployment Force, of which the MPWS is an essential element. The study therefore took on added importance, and its results were presented to the Commandant of the Marine Corps, the planning staff of the U.S. Army, and Congressional staffs.

The study concluded that none of the candidate systems now available could meet all of the Marine Corps' requirements. But the evaluation pointed to several hybrid designs worth further consideration. In September 1980, manufacturers were asked to submit proposals for the manufacture of an MPWS. The request for proposals specified design criteria that are based on CNA's findings.

The Marines are also considering new trucks, trailers, and helicopters for use in combat.

The new trucks and trailers are of 1/4- to 5/4-ton capacity. CNA has evaluated four choices in terms of costs and such measures of performance as mobility, acceleration, and transportability. The choices were: replacement in kind, procurement of existing commercial vehicles, procurement of foreign military vehicles, and development of a conceptual high-mobility multipurpose wheeled vehicle (HMMWV). Commercial vehicles proved the least expensive but the poorest in off-road mobility. Foreign vehicles are more mobile but cost the most. The conceptual vehicle, the HMMWV, appears to afford the best balance of cost and performance, though it entails the greatest technological risks. On the basis of CNA's analysis, the Marine Corps is requesting funds for development of the HMMWV.

The Marines rely on CH-46 helicopters to lift medium-sized loads — including troops, weapons, equipment, and supplies — from amphibious ships to landing zones and to support combat operations ashore. These helicopters are expected to reach the end of their useful life by

1990, and the search for a replacement has begun. CNA has studied four designs that vary considerably in speed and, therefore, in cost. Equal-cost forces of the candidates, which ranged from an advanced helicopter to an aircraft with tilt-rotors, were measured against two standards: the time required to deliver the first assault elements of a landing force and the percentage of aircraft shot down by enemy defenses. No significant differences were found.

LOGISTICS, PROCUREMENT, AND MANPOWER

Access to Indian Ocean Facilities

CNA has investigated the prospects for U.S. access to naval facilities around the Indian Ocean, access that could prove valuable in view of the United States' commitment to the security of Southwest Asia.

To gauge the prospects and the associated risks, it was necessary to analyze the extensive experience of the Soviet Union with access to facilities in Indian Ocean states and in other nations of the Third World. U.S. experience, which consists mainly of dealing with U.S. allies or former colonies of allies, is of only limited value toward understanding what may lie ahead in the Indian Ocean.

In drawing upon the lessons of Soviet experience, it is important to keep in mind the distinction between *bases*, which may be used at will, and *facilities*, which are used at the discretion of the host nation. Political considerations will play a major role in determining how, when, and whether the facilities are used. Because of the unpredictable and rapidly changing circumstances typical of the Third World, access to a given country's facilities is not likely to last long. In Egypt and Somalia, for instance, Soviet access was relatively brief — in fact, lost before the Soviets could use costly installations they had built, notably the large airfield at Berbera, Somalia.

The ultimate costs of access may prove far higher than the initial outlays for facilities used by U.S. forces. In Somalia, for example, the Soviets modernized the Somali armed forces in exchange for access to local facilities. Somalia was thus enabled to unleash an irredentist war in the Ogaden that proved costly to the Soviets, both economically and politically. To reduce the political and economic costs of tenuous

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relationships, the Soviets rely wherever possible on temporary and mobile facilities, such as communications vans, prefabricated housing facilities, floating dry docks, and yard oilers.

If the nation that is asked for access expects more in return than is promised or delivered, bargaining is likely to continue, even after agreements are signed. Because the Soviets were unwilling to support Somalia's irredentist ambitions, access privileges were the subject of intense bargaining, and each side withheld what the other side wanted (i.e., access for the Soviets, arms for the Somalis) until concessions were made. Moreover, even after access privileges were granted, there were delays in the construction of facilities because of disputes over future use.

What Spare Parts Should Be Stocked on Ships?

A frequent complaint from the fleet is that only half the parts needed for repair of shipboard equipment are actually carried aboard ship. CNA looked into the matter, to determine what changes, if any, should be made in the Navy's current policy on consolidated shipboard allowance lists (COSALs). This policy prescribes the repair parts stocked aboard ship.

CNA found that because of the extreme variances in failure time of equipment, many parts that are not carried on an allowance list do fail, and many parts that are carried do not. CNA also found that the present policy leads to deficiencies in two classes of parts whose demand rates are just below the threshold for stocking: those demanded once every four to ten years and those demanded two to four times a year. Such parts constitute about 10 percent of the replaceable items aboard a frigate. Moreover, the present policy takes no account of the relative importance of the functions supported by the parts.

The pertinent costs of carrying repair parts are related to the costs of parts that are discarded unused. In total life-cycle cost, parts provided by both the initial allowance and the supply system are many times as expensive as parts that are unused. The life-cycle cost of a ship's COSAL is therefore much lower than is generally perceived.

The life-cycle costs of frigates, for instance, are 300 to 400 times as high as the costs of their fully stocked COSALs. In other words, onboard stockage is a relatively inexpensive means of keeping a ship's equipment ready for action. If repair parts are stocked aboard, they can be available in two hours; otherwise, the delay is as long as eight to seventy-five days.

The study recommended these changes in policy:

- Identify parts critical to the primary missions of the ships.
- Increase the stockage of primary-mission parts demanded every four to ten years and two to four times a year.

As a result, the time a ship is not ready for lack of parts would be reduced by about 50 percent. The life-cycle cost of repair parts would increase by only five to ten percent.

The Chief of Naval Operations has directed the Naval Material Command to carry out the recommendations.

Disruption Costs in Shipbuilding

Changes in naval ship specifications during construction have added significantly to costs.

By 1977, outstanding claims by shipbuilding contractors reached the unprecedented level of \$2.7 billion. About 80 percent of this amount was attributed to delays and disruptions of work as a result of changes in plans and specifications. The Chief of Naval Material asked CNA to determine the feasibility of relating the costs of disruption and delay to the basic costs of changes generally accepted by both the Navy and its contractors — hard-core change hours.

Estimating and settling the full costs of changes during construction on the basis of this relationship could reduce the total costs of changes, as well as the number of claims and the costs of settling them.

Drawing on data from the Avondale FF 1052 program and Litton DD 963 program, the CNA study group developed a statistical model

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of shipbuilding man-hour costs. The model estimates the effects on total man-hour costs of changes and of such other variables as learning, labor turnover, skill level, manning level, and the amount of other construction going on in the shipyard.

The analysis showed that changes do affect the total man-hour costs of ship construction by an amount significantly greater than the cost of hard-core changes alone. Learning, manning, labor skills, experience — and, in the case of the DD 963 program, the amount of other construction in the yard — also affect man-hour costs. The analysts found, moreover, that the costs of disruption caused by changes increase with increases in manning and the rate of turnover. The analysts developed techniques for estimating the costs of delays induced by changes.

The study demonstrated that costs of delay and disruption can be quantified by statistical analysis. Further, the technique can be used in continuous updating of the pricing of changes as construction goes on.

How Good Are the Aptitude Tests?

Before any of the armed services accepts prospective recruits, the likelihood that they will complete their training is measured by means of the Armed Services Vocational Aptitude Battery (ASVAB). If the results match levels of aptitude that indicate success in military training, the recruits are considered mentally qualified.

Accepted testing procedures require occasional replacement of aptitude tests by new versions of equal difficulty. New versions of the ASVAB must therefore be calibrated to older tests; that is, the number of questions answered correctly (the raw score) must be related properly to the standard military score scale. If this relationship is established properly, the new test will measure aptitude for training just as accurately as the earlier test.

CNA has conducted two analyses of the calibration of the present forms of the ASVAB. The first, done at the request of the Marine Corps and described in CNA's Annual Report for 1978, showed that the ASVAB was incorrectly calibrated, that more low-aptitude

recruits were being enlisted than the Department of Defense (DoD) had reported.

At the request of DoD, CNA conducted a second analysis, based on data collected specifically for test calibration. Both the preliminary results of this analysis (reported in CNA's Annual Report for 1979) and the final results show that the test calibration was even less accurate than the first analysis had found. The ASVAB greatly overstates the ability of recruits, thus resulting in serious errors in official statistics concerning the mental aptitude of recruits.

To check the findings of the second study, DoD sponsored two independent studies of calibration of the ASVAB. Both confirmed CNA's findings. DoD therefore reported to Congress that official statistics about the mental aptitudes of recruits had been wrong since 1976 and that approximately six times as many low-aptitude recruits had been accepted as had been thought.

CNA, in addition to its work in identifying and measuring the calibration error, has worked with a joint service group to design, construct, and calibrate new forms of the ASVAB. They went into use in late 1980.

How Can the Navy Screen Its Recruits Better?

With the arrival of the all-volunteer armed force in 1973, the Navy grew concerned about the losses of first-term enlistees before the end of their obligated service. Nine percent of the recruits who entered in 1973 were discharged during recruit training, and 17 percent were discharged during their first year of service. Such premature losses are a continuing source of concern to the Navy because they are costly and interfere with training and fleet readiness.

CNA was asked to help the Chief of Naval Personnel establish criteria for screening out recruits who are unlikely to complete their obligated service. CNA's specialists in personnel matters developed a model that relates background characteristics of recruits to their survival behavior, that is, how long they stay in the Navy after enlistment. Profiles were then developed to distinguish between recruits who are likely to leave early and those who are likely to complete their first term of service. The Navy adopted these profiles

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for recruit screening in 1976. CNA is now developing faster and less expensive methods to provide profiles in the future.

Until now, survival models have been based on data for cohorts of recruits who enter the Navy in the same calendar year; each recruit is followed individually until he leaves the Navy. Use of such data is risky because the data may not reflect survival patterns in effect at the time they are analyzed. In any event, it takes a long time to collect the cohort data needed to update survival profiles. CNA therefore decided to develop ways of estimating survival chances without cohort data. This is being done through a special statistical technique applied to data for all enlisted personnel in the Navy in December 1978.

The biostatistical technique, called the Cox regression model, has two advantages. First, it yields curves showing the survival chances of recruits, from entry to the end of their first enlistment, instead of point estimates of survival at the end of first enlistment. The second advantage is that the Cox regression model can be applied to cross-sectional data, making it unnecessary to track a cohort of enlistees for several years. The December 1978 data base will yield up-to-date, accurate profiles for the Navy to use in its screening policies.

Keeping Enlisted Careerists in the Navy

In addition to research into recruiting and screening of recruits, CNA has conducted a series of analyses relating compensation to retention, that is, willingness of enlisted personnel to stay in the service. In 1980, therefore, the Office of the Secretary of Defense asked for a study of the effects of compensation on the retention of enlisted personnel since the end of the draft. The loss of enlisted careerists is probably the Navy's most important personnel problem today. Estimates were needed of the pay levels that would induce them to stay.

The many past studies on compensation and retention have significant limitations. First, most of them have relied on data from the draft era, but the relation between pay and retention may have changed with the end of the draft. Second, only first-term reenlistments have been considered; the effects of pay raises on later reenlistment decisions could only be inferred from these studies. Third, most of the earlier studies have derived single estimates of the effects of

pay changes by grouping data on bonuses and reenlistment rates for several military occupations; yet, occupational groups may differ systematically in their response to pay changes. Finally, earlier studies have estimated the immediate effects of first-term reenlistment bonuses, but not their effects on second-term reenlistments.

The CNA study estimated the effects of pay raises on both first- and second-term reenlistment decisions, using time-series data for post-draft years. The analysis also yielded separate estimates of the effects of raises on retention in 28 occupational groups. Finally, the effects of first-term bonuses on second-term reenlistments were determined.

The study drew on data for every Navy enlisted man who made a first- or second-term reenlistment decision between FY 1974 and FY 1978. These men were separated into 28 occupational groups; the statistical relationship between the military-civilian pay differential and reenlistment propensity was estimated for each group. Reenlistment propensity proved to be related significantly to the military-civilian pay differential at the time of both the first- and second-term reenlistment decisions. Pay does matter.

Some occupational groups are more responsive to pay changes than others. In most of the occupations exhibiting low responsiveness, the proportion of sea duty is high. Conversely, the occupations showing high responsiveness to pay changes involve relatively little sea duty. The results suggest that seagoing occupations require larger raises in pay than other occupations.

In the analysis of second-term reenlistments, the size of an individual's first-term bonus was included as an explanatory variable. The effect of this variable was usually found to be negative and statistically significant. This means that individuals who are induced to stay because of higher first-term bonuses are in fact less career-committed and therefore less likely to reenlist after a second term. In current force planning, retention rates at various terms of service are viewed as independent of one another; the future effects of changes to first- or second-term bonuses are not considered. The results of the CNA study suggest they should be.

METHODS OF MILITARY OPERATIONS RESEARCH

A Campaign Analysis Revisited

As noted in section I of this report, CNA's efforts to maintain its high standards of quality lead it to occasionally reconsider the types of research it does and the methods used.

Over the years, the CNA research program has included a number of large-scale studies of naval campaigns. Campaign studies are intended to gauge the effectiveness of military forces in an extended series of battles. If estimates of the effectiveness of military forces are seriously flawed, the lessons drawn from them are likely to be misleading.

In 1980, therefore, CNA analysts looked at the War at Sea II (WAS II) study. This campaign analysis, conducted by CNA in 1968, examined the course and outcome of a major naval war between the U.S. and the Soviet Union in 1975. The outcome of the war depended on estimates of the sizes of forces on both sides, as well as individual performance and tactical use. It is the accuracy of these estimates that was evaluated.

Had there been a major naval war between the U.S. and USSR in 1975, it might well have turned out differently from the outcome indicated in WAS II. But the main purpose of campaign analysis is not prediction of victory or defeat. Rather, it is to identify critical factors that may determine the outcome of a campaign. WAS II conducted many sensitivity analyses to investigate the effects of changes in the make-up and performance of forces. But no systematic attempt was made to identify the most critical of these parameters, to identify for decision-makers the weaknesses in the Navy's planned posture.

The main lesson drawn from this retrospective study is that campaign analyses should focus more sharply on the major determinants of force effectiveness and give less emphasis to the estimated results of campaigns. The lesson has been applied to a recent CNA study of a naval campaign. In addition, the details of the retrospective study and lessons learned from it have been presented widely throughout the

analytical community and to defense officials — for the general benefit of defense analysis.

Surveys of Methodology

To help new staff members become more familiar with the methods of warfare analysis, CNA has published several compendia of analytical methods. Three such volumes were completed in 1980. One considers the nature of underwater sound and the methods used to detect and analyze the nature of a target through underwater acoustics. A second describes the various mathematical models that are used to describe the detection process in a dynamic encounter between a detector and a target. The third deals with the effective range of a detector, as well as statistical techniques for estimating the performance of a sensor from exercise data.

Naval Abstracts

CNA continues to provide its unique indexing service. *Naval Abstracts*, issued quarterly, abstracts and indexes articles on naval subjects and on broad political and strategic subjects involving the Navy. Several hundred journals in the open literature are reviewed, including selected articles printed in French, German, Italian, and Spanish journals. Subject and author indexes are included in each issue, and the fourth issue of each year includes a cumulative subject index for that year. *Naval Abstracts* is provided to the Navy and others in the defense, research, and academic communities. Other organizations, as well as individuals, may subscribe.

NON-DEFENSE RESEARCH

How Imports Affect Employment

Rising imports in a variety of industries have been blamed for unemployment, despite evidence that points to other causes. Further, federal programs have been set up to help workers cope with unemployment attributed to imports. These programs have become so costly that the Labor Department asked CNA's Public Research Institute (PRI) to investigate the effects of increases in imports on

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output in a competing U.S. industry and, in turn, on employment in that industry.

The CNA study considered whether rising imports today mean that an industry should expect worse times in the future. To find the answer, the study team developed and tested a theoretical model relating the current demand for employment to current and future output.

Most earlier studies have assumed that future output has no serious effects on current employment. This assumption is reasonable for industries whose workers are relatively unskilled and can therefore be hired and trained at low cost. In industries where such costs are high, however, firms must weigh the costs of holding unneeded workers today, when output is low, against the costs of hiring and training new workers tomorrow, when output recovers. The higher these costs, the greater is the effect of future output on today's employment. The CNA analysts accounted explicitly for this relationship in the economic model they developed. They then tested the model, using data for 11 manufacturing industries where imports are thought to be a problem.

The test required data on the Gross National Product, as well as on employment, output, imports, and prices in each industry. First, the data were used to determine the relationship between imports and industry output.

Next, this relationship was used to estimate future output. Finally, an explicit relationship was established between current employment and both current and expected output. An important feature of the analysis is that the model and empirical results make possible a comparison of the effects of changes in GNP and imports on the current demand for employment.

The study led to two important conclusions. First, expectations of future output are important in eight out of the eleven industries studied. This indicates that what firms *believe* will happen affects their current demand for workers. Even a simple expectation model yields better results than models that rely entirely on current output.

The second conclusion is that imports affect employment far less than an equivalent change in GNP. Though imports have an important influence on demand for labor, past studies have exaggerated this importance.

Evaluating Unemployment Insurance Tax Systems

Unemployment insurance (UI) benefits are financed by state taxes on employers. The wide diversity of tax systems among states has received a great deal of attention recently because many state UI funds have run out of money.

When such a fund does run out, the state borrows from a federal trust fund that is financed by a tax on employers in all states. There is a great deal of disagreement over how and when debts to the federal trust fund should be repaid. No one wants to add to the tax burden on firms, especially during a recession. But there is growing concern that the tax systems of some states cannot support their benefit schedules. These states are therefore being subsidized by states that have higher taxes and never need to borrow from the federal trust fund.

PRI conducted a study for the National Commission on Unemployment Compensation to help UI administrators evaluate tax systems and predict how changes in tax systems would change fund balances. Several models of UI tax systems were developed, and their predictive power was tested. The best models were used to predict fund balances under a variety of hypothetical tax systems.

The adequacy of fund balances was also evaluated. Federal administrators now consider a fund adequate if the balance is a specified multiple of annual wages "at the beginning of a period of relatively high unemployment." Aside from the difficulty of determining when "relatively high unemployment" begins, this measure treats solvency as the only criterion for evaluating fund balances. States can keep their funds solvent by maintaining arbitrarily high balances or by raising taxes immediately when benefit outflows start to rise. But very high balances represent idle funds that could have been used productively by the employers who pay unemployment insurance taxes. And raising taxes when benefit outflows begin to rise means high taxes in a recession.

32 / II. 1980 Results

To reflect the actual — often competing — goals of UI fund managers, the study team measured UI tax systems by three criteria: the mean balance, the probability of insolvency, and the timing of the tax over the business cycle. A good tax system will produce a fund with a low mean balance and a low probability of insolvency, and will raise taxes in a boom rather than in a recession.

Simulations of many different tax systems for many different states showed that almost all state tax systems can be improved, the changes required varying from state to state. The study concluded that a single, federally-mandated tax system would not suit all states. The best tax system for a state depends on, among other things, the amount of seasonal employment and the variations in employment over the business cycle. A better way to finance UI benefits would be to charge interest on loans from the federal trust fund and to set a minimum repayment schedule. These measures would encourage states to adopt fiscally-sound tax systems suited to their own conditions.

RESEARCH AT THE UNIVERSITY OF ROCHESTER

The agreement between the Navy Department and the University of Rochester does not provide a management fee. Instead, five percent of CNA's budget is allocated to unclassified research at the University on subjects of long-term interest and potential value to the Navy. The subjects range over various disciplines, including the physical and engineering sciences, applied mathematics, medicine, and economics and other social sciences. This was the program supported during the 1979-80 academic year:

Arts and Science

- Hemispheric Differences in Evoked Potentials to Relevant and Irrelevant Visual Stimuli
- Study Three Parameter Reliability Distribution with Applications to Electronic Component Failure
- Mechanisms of Very Heavy-Ion Reactions
- Legitimacy, Competency and Organizationally Produced Sex-Differences
- Study of Arachnids and Other Arthropods in the Ecology of the U.S. Virgin Islands

Behavioral Self-Control and Recovery from Alcoholism
Galaxy Kinematics

Engineering and Applied Sciences

**Taylor Dispersion in Systems of Sedimenting Nonspherical
Brownian Particles: II. Homogeneous Ellipsoidal Particles**
**A Micromechanical Derivation of the Differential Equations of
Interfacial Statics**
Emulsions Containing a Third, Solid, Internal Phase
Nonlinear Spectroscopy of Solids
Automated Synthesis Technique for Distributed Parameter Systems
Statistical Optics and Scattering
Diffusion and Reaction of Ions in a Double-Layer
Shift Operators and Nonlinear Systems Theory
Dynamics of Passive Solar Collector Systems
Velocity Measurements Near a Fluid-Air Interface
Microprogrammable Classified for Cancer Cells
Electrostatic Effects on Description of Surfactants
**Interfacial Energy as a Descriptive Parameter of Fatigue Micro-
structures**
Photocatalytic Processes on Alkali Halides
Microwave Theory of Josephson Oscillators
Efficient Pumping of Highly Excited Atomic States

Graduate School of Management

**An n-Constraint Formulation of the (Time Dependent) Traveling
Salesman Problem**
The Traveling Salesman Problem and Related Problems
Mathematical Formulations for the Dial-a-Ride Problem
Consumer Responses to Price Discounts

School of Medicine and Dentistry

Growth Modification Caused by Narcotic Gases
Image Scanning Facility & Universal Computer Coupler

School of Nursing

**An Experimental Study to Examine Means of Enhancing Empathy
and Effectiveness of Nurses in Stress Situations**

III. ORGANIZATION

The organization of CNA is depicted on page 36. The four operating groups, which conduct the Center's research, are generally supervised and supported by the Office of the President; this assistance includes the contribution of the Computing Services section and the participation of the Naval personnel assigned to the Operations Study Group. The Board of Overseers regularly reviews the quality of CNA's research and management. (See section VI of this report for a description of the Board's responsibilities and membership.)

OPERATING GROUPS

Each of the four operating groups — the Operations Evaluation Group, Naval Warfare Analysis Group, Institute of Naval Studies, and Marine Corps Operations Analysis Group — has its own field of specialization.

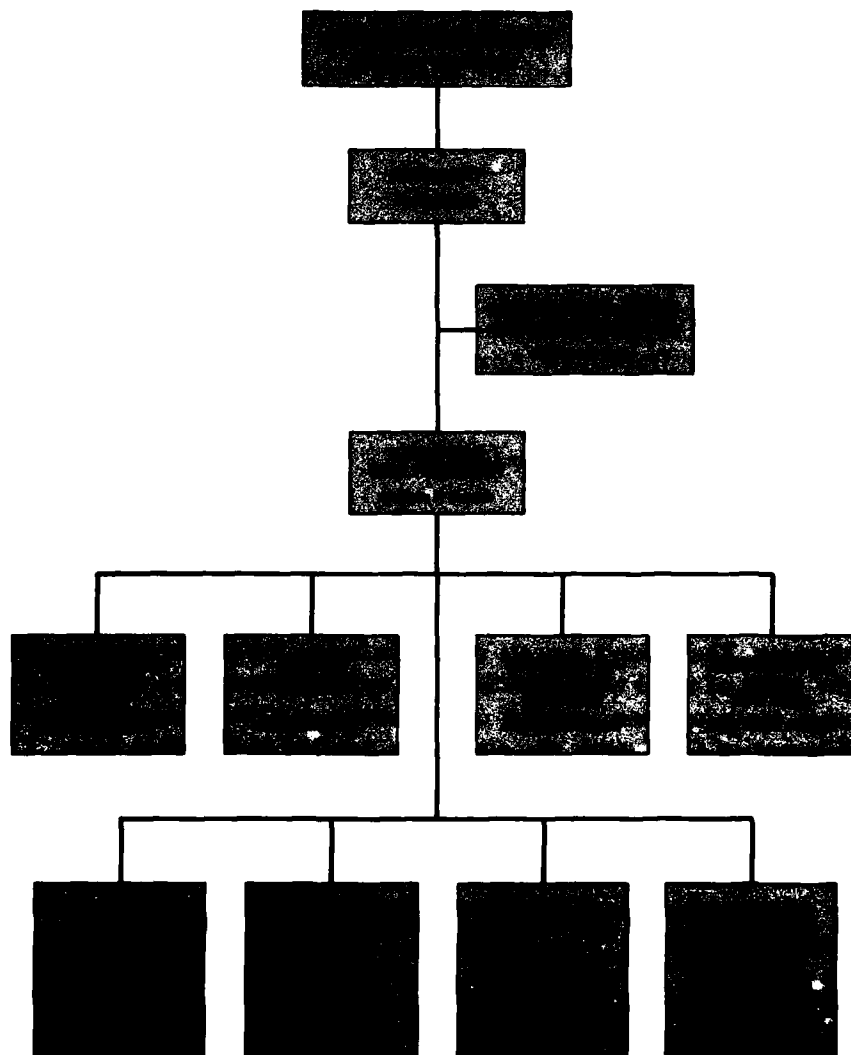
Operations Evaluation Group (OEG)

OEG has the longest history of any of CNA's operating groups, dating back to 1942, when it was known as the Anti-Submarine Warfare Operations Research Group (ASWORG). At first, the group helped devise ways of combating the German U-boat attacks on U.S. shipping. The group's success in this endeavor led to a broadening of the types of naval warfare to which it applied quantitative analysis. A main result of these wartime contributions was the permanent establishment of OEG, with the support of Admiral of the Fleet Ernest J. King.

The field program, also born of World War II, remains an important part of OEG's activities. OEG's field representatives return after one- or two-year tours with the fleet and are replaced by others from the Washington office.

There is thus a continuing infusion of practical experience into CNA's formal studies. This is matched by a counter-infusion of up-to-date knowledge of analytical techniques into OEG's field program. CNA and the Navy have long felt that this program leads to far more practical and realistic analyses than would be possible if the analysts

THE ORGANIZATION OF CNA



never left their desks in Washington. OEG has a professional staff of more than 60, of whom 35 are assigned to these Navy commands:

Atlantic Area

Brunswick, Maine

Commander, Patrol Wings, Atlantic Fleet

Newport, Rhode Island

President, Naval War College

New London, Connecticut

Commander, Submarine Development Squadron Twelve

Patuxent River, Maryland

Air Test & Evaluation Squadron One

Norfolk, Virginia

Commander-in-Chief, Atlantic/U.S. Atlantic Fleet

Commander, Naval Air Force, U.S. Atlantic Fleet

Commander, Second Fleet

Commander, Surface Warfare Development Group

Commander, Tactical Wings, Atlantic Fleet

Commander, Operational Test & Evaluation Force

Charleston, South Carolina

Commander, Cruiser-Destroyer Group Two

Commander, Mine Warfare Command

Jacksonville/Mayport, Florida

Commander, Cruiser-Destroyer Group Twelve

Commander, Sea-Based ASW Wings, Atlantic Fleet

European Area

London, England

Commander-in-Chief, U.S. Naval Forces, Europe

Gaeta, Italy

Commander, Sixth Fleet

Naples, Italy

Commander, Attack Carrier Striking Force, Sixth Fleet

Commander, Submarine Force, Sixth Fleet

Commander, Maritime Surveillance & Reconnaissance Force,
Sixth Fleet

Commander, Area Antisubmarine Warfare Force, Sixth Fleet

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Pacific Area

Whidbey Island, Washington

Commander, Medium Attack Tactical Electronic Warfare Wing,
U.S. Pacific Fleet

Moffett Field, California

Commander, Patrol Wings, Pacific Fleet

Pt. Mugu, California

Air Test & Evaluation Squadron Four

Lemoore, California

Commander, Light Attack Wing, Pacific

San Diego, California

Commander, Naval Surface Force, Pacific Fleet

Commander, ASW Wing, Pacific Fleet

Deputy Commander, Operational Test & Evaluation Force,
Pacific

Commander, Fighter Airborne Early Warning Wing, Pacific Fleet

Tactical Training Group, Pacific

Pearl Harbor, Hawaii

Commander-in-Chief, Pacific Fleet

Commander, Third Fleet

Commander, Submarine Force, Pacific Fleet

Kamiseya, Japan

Commander, Patrol & Reconnaissance Force, Seventh Fleet

Yokosuka, Japan

Commander, Seventh Fleet

Subic Bay, Philippines

Commander, Attack Carrier Striking Force, Seventh Fleet

The main emphasis in OEG remains what it was in the earliest days of the organization — getting the most out of the forces at hand and sending scientists to sea to help in that process. OEG is concerned with how best to use the Navy the nation has today and is committed to for the next few years. This is the concern not only of OEG's field representatives, but also of its Washington-based analysts, who both conduct their own research and augment the efforts of their colleagues in the field.

As the Navy has changed, so has OEG, especially in the kinds of projects it undertakes. But OEG's mode of operation has not changed significantly since its inception. OEG pioneered in the development of military operations research techniques and in creating the close

working relationship between civilian scientists and Naval personnel that continues to this day.

Over its lifetime, OEG has trained hundreds of operations analysts. Its "alumni" are scattered throughout the government, the academic world, and industry; both directly and indirectly, the organization's efforts continue to benefit the nation.

Naval Warfare Analysis Group (NAVWAG)

In 1979, the Systems Evaluation Group was merged into NAVWAG. The merger strengthened CNA's ability to analyze the costs and effectiveness of future naval systems. In 1980, the study program has grown to include mid-range and long-range research in these major aspects of naval warfare:

- Anti-air warfare
- Anti-submarine warfare
- Submarine warfare
- Amphibious and mine warfare
- Command, control, communications, and intelligence
- Strategic warfare.

Many NAVWAG studies require analyses of several aspects of naval warfare; two such studies now in progress are an analysis of possible conflicts in the Indian Ocean and an assessment of the long-term implications of petroleum shortages.

In general, NAVWAG's studies involve cost-effectiveness comparisons of alternative combatant forces and related systems. Even the studies that do not compare alternatives often look into the cost, as well as the effectiveness, of systems under consideration. For this reason, NAVWAG has established a Cost Analysis Division, from which experienced cost analysts are assigned to support major studies. The division also conducts its own studies, including an analysis of the rise in ship procurement costs.

Some of NAVWAG's work involves tasks — mostly for the Navy — that are funded apart from the basic contract. These are the responsibility of the Future Tactics and Systems Division. As its name suggests, the division's research is concerned with helping the Navy to develop the best tactics for the weapon systems it plans to buy, determine how many to buy, and find innovative solutions to the problems of naval warfare through new system designs.

NAVWAG has a staff of 42 professionals.

Institute of Naval Studies (INS)

INS was established as an independent organization in 1960. In 1962, it was combined with OEG to form CNA. Since then, the focus of INS research has been on politico-military affairs, strategic planning, manpower, and logistics — concerns that cut across the many types of warfare analyzed in OEG and NAVWAG. INS has a professional staff of 35.

Its Manpower Studies Division analyzes policies for recruiting, training, and retaining enough qualified personnel for the armed forces. This division also develops tools for better management of personnel. A Readiness and Logistics Division analyzes policies and expenditures affecting procurement, supply, transport, and maintenance. This division seeks to raise the efficiency with which funds for material support are used. A Strategy Division analyzes political and military issues, as well as developments in Soviet military strategy, with an eye to anticipating the tasks the U.S. Navy may be called upon to carry out. Findings are used in national intelligence estimates, net assessments of the naval balance, and the long-range plans of the Office of the Chief of Naval Operations.

Another component of INS is the Public Research Institute (PRI), which conducts CNA's program of economic research for non-defense agencies of the government. In 1970, the Secretary of Defense suggested that the talents and techniques that had been applied successfully to defense analysis by such organizations as CNA be applied to non-defense problems in the public sector, as well. CNA responded by establishing PRI, which has worked on such subjects as the economic effects of pollution controls, the effects of imports on employment, the employment implications of technical progress, and

the adequacy and economic effects of unemployment insurance systems.

Marine Corps Operations Analysis Group (MCOAG)

MCOAG was established as a CNA operating group in 1965. Its professional staff of 20 analyzes a wide range of problems for Marine Corps Headquarters in Washington and for field commands. MCOAG research involves such aspects of warfare as amphibious assault, ground combat, tactical air warfare, and antiair warfare, as well as such related areas as manpower and logistics. Because it is involved in warfare analysis (as NAVWAG is), conducts manpower and logistics analysis (as INS does), and participates in field operations (as OEG does), MCOAG can be thought of as a microcosm of CNA.

For its analyses of amphibious warfare, MCOAG has developed a series of computer models that design alternative forces and evaluate them. One model creates equal-cost mixes of amphibious ships, landing craft, assault vehicles, and helicopters. These forces are then evaluated by means of a large-scale computer model that simulates the major combat activities of an amphibious assault. This model has been used to evaluate mixes of tactical aircraft, new infantry organizations, and concepts of operations. The set of models has been used to analyze equal-cost mixes of landing craft and amphibious ships for the Navy and equal-cost mixes of assault vehicles for the Marines.

MCOAG, like other operating groups, has done work in response to Congressional interest. One such analysis has been the evaluation of foreign, lightly armored vehicles that the Marine Corps might use for antitank and infantry support missions. MCOAG analysts have also looked into the value of new intelligence and command and control systems, and the benefits of the increased speed offered by advanced-technology helicopters and other VTOL aircraft for amphibious assault.

Analyses of Marine Corps manpower problems account for another significant portion of the MCOAG study program. Emphasis has been placed on development and analysis of mental aptitude tests for prospective recruits, relationships between scores on these aptitude tests and the performance of individual Marines, as well as manpower requirements, supply, and recruiting.

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More than half of MCOAG's analysts have served as field representatives at Marine Corps and Navy commands, and the group maintains field billets at the headquarters of the Fleet Marine Forces in Honolulu, Hawaii, and Norfolk, Virginia, and at the Marine Corps Development and Education Command in Quantico, Virginia.

OFFICE OF THE PRESIDENT

The *President of CNA* is responsible to the Board of Overseers and the University of Rochester for all of CNA's activities. He selects the management, organizes the Center's activities, sees to the quality and pertinence of its work, makes certain that it meets its contractual and security obligations, and sets its policies and budgets. The President also attends to external relations: with the Department of the Navy, with the broader community of national security analysts, and with the analytical profession generally.

The *Executive Vice President* is primarily responsible for the timely planning, execution, review, and publication of CNA's research. To monitor the progress of studies, he oversees the milestone reporting system. He also approves the hiring and assignment of all members of the CNA professional staff, reviews their performance, and sets their salaries.

The *Director of Program Review* monitors the quality of CNA's research for the President and Executive Vice President. He checks CNA's analytical approach to each study, follows its progress, and reviews the finished product to see that CNA's work meets the University's standards of analytical quality and that the results are so presented as to be clear and useful to decision-makers.

The *Senior Scientist* conducts special analyses and projects requiring unusual analytical talent and experience, and supports both the planning and reviewing activities. He also directs CNA's program of training for its new professional staff members and organizes series of guest lectures by experts in operations research.

The *Director of Finance and Administration* is responsible for all matters relating to financial and contractual management, for programs affecting physical security, for publication and distribution of

research reports, and for the operation of the Personnel Department. He is responsible for assuring compliance of CNA's security practices with the Industrial Security Regulations of the Defense Investigative Service.

The *Director of Computing Services* is responsible for operation and utilization of the computer center, for centralized programming, and for a proper match between the capabilities of the computer center and the needs of the CNA research program. Under his direction, the Computing Services staff provides computing, consulting, and programming support for the CNA research program and for CNA's administrative departments.

The *Director for Naval Matters*, a senior Navy captain, is assigned to the Center by the Scientific Officer for CNA (Op-090), with the concurrence of the President of CNA. The DNM has administrative responsibility for the Operations Study Group (see below). He is an ex officio member of the management staff, participates in the planning and review of studies, and maintains liaison with the Bureau of Naval Personnel to keep the OSG staffed with qualified personnel. He also conducts special analyses within the CNA program, as directed by the President.

RESEARCH SUPPORT ACTIVITIES

The *Operations Study Group* comprises the 25 Naval officers and six enlisted personnel assigned to CNA as working members of the analytic and support staffs. They are selected on the basis of military experience and performance, as well as academic background (19 of the 25 officers have advanced degrees).

Though the members of OSG report to the Director for Naval Matters for administrative purposes, they are otherwise completely integrated into CNA's operating groups, working side by side with civilian professionals. While they are in OSG/CNA, their work is directed by the President of CNA, not by the Navy.

Aside from their valuable analytical contributions, the members of OSG provide CNA's research staff with practical experience, technical knowledge, and a constructive user's point of view. They are quick to

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point out any discrepancies between theoretical analyses and the realities of naval warfare. Furthermore, the OSG program provides practical training in applied analysis for these personnel, who — together with the Navy itself — will benefit from the experience when they move on to higher positions.

The *Computing Services* staff provides analysis and programming for design, development, installation, and maintenance of software systems in three broad areas:

- Systems programming — the master control program, programming-language systems, utility programs, communications systems, and performance-measurement tools
- Applications programming — naval warfare models, interactive graphics and plotting software, simulation software, software and applications for data base management systems, statistical software, and Research Analysis Language (RAL)
- Operations — file archiving, storage media transfer, and operational software.

Other support activities are conducted by four administrative departments, reporting to the Director of Finance and Administration: *Finance and Accounting* provides cost and management accounting reports, financial management services, contract administration, and procurement services. *Personnel* provides recruiting, interviewing, and testing services, maintains personnel records, administers the salary and fringe benefits program, and manages CNA's Equal Employment and Affirmative Action programs. *Information Services* has two main functions in support of research: (1) acquisition, dissemination, and control of research resource materials, and (2) production and distribution of completed research reports. This department is also responsible for managing CNA's library. *Security* assures compliance with the Industrial Security Regulations of the Defense Investigative Service and is responsible for providing building maintenance and office service support.

IV. PERSONNEL

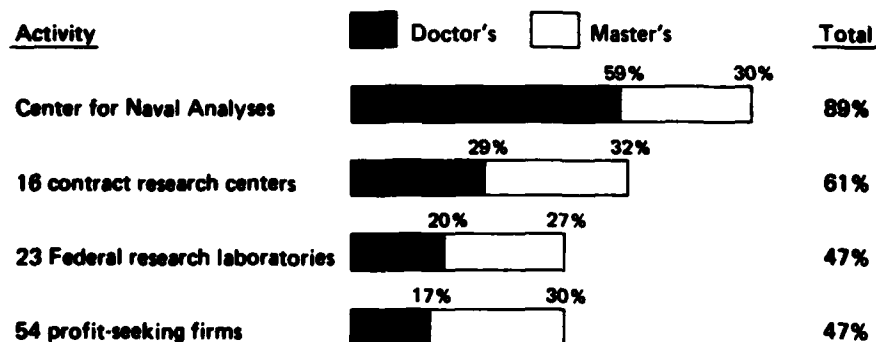
Management by the University of Rochester gives CNA a unique advantage in attracting and retaining a professional staff of high quality. The recruiting program is designed to draw new talent from top-rated colleges and universities across the nation and to attract professionals with a record of accomplishment in defense research.

STAFF COMPOSITION

CNA's professional staff is well suited to conducting research of critical importance to the nation's defense. The staff is highly educated and experienced; most of its members hold advanced degrees.

The proportion of CNA staff members holding advanced degrees is much higher at CNA than in similar research organizations:

POSTGRADUATE DEGREES (Proportion of professional staff, 1980)*



*Source: "National Survey of Compensation Paid Scientists and Engineers Engaged in Research and Development Activities," Battelle Memorial Institute, Columbus, Ohio, November 1980.

The quality of the postgraduate education received by CNA's staff is also high: Almost two-thirds of the institutions at which staff members earned advanced degrees are top-rated in the applicable specialties, according to a survey published by the American Council on Education. CNA supports continuing postgraduate education of staff members through its program of tuition assistance and professional development.

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This was the background of the CNA professional staff on 30 September 1980:

- Average postgraduate education 3 years, 11 months
- Average career experience
 - Total 10 years, 5 months
 - Directly related to CNA research 8 years, 9 months
- Proportion with field experience 48 percent
- Average cumulative time in the field* 3 years.

**Of analysts with field experience.*

These are the disciplines represented in the professional and management staffs on 30 September 1980:

	<u>Number</u>	<u>Fraction of staff</u>
Physics and chemistry	54	29%
Mathematics and statistics	38	21%
Economics, business, and finance	32	17%
Engineering	20	11%
Operations research	12	6%
Political science and international relations	7	4%
History	3	2%
Psychology and sociology	3	2%
Other	<u>15</u>	<u>8%</u>
TOTAL	184	100%

SALARIES

The Executive Vice President of CNA approves all offers of employment and all actions affecting professional staff salaries. Any salary

above the maximum paid under the Civil Service General Schedule (\$50,100 in October 1980) must also be approved by the Executive Committee of the CNA Board of Overseers and by the Navy's Contracting Officer. Recent legislation also requires the Secretary of Defense to notify Congress annually about every FCRC officer whose compensation out of federal funds exceeds the pay authorized for level II of the Executive Schedule (now \$70,900).

CNA's management uses salary survey data to make sure that CNA salaries are competitive. The surveys include salary data for a large national sample of scientists and engineers by degree, specialty, and level of experience. This information is supplemented by informal exchanges with organizations conducting research similar to CNA's. Salaries and individual contributions to the research program are reviewed every year.

EQUAL OPPORTUNITY

CNA has long supported the principle of equal opportunity, regardless of race, creed, color, national origin, sex, or physical handicap. To that end, CNA has established policies and practices in conformity with federal legislation. The main purposes of CNA's Affirmative Action Program are: (1) to make sure that, within each sector of the labor market drawn on by CNA, minorities and women are represented on the CNA staff to the same degree as they are in the sector as a whole, and (2) to provide all employees with opportunities for training and advancement. CNA is dedicated to these objectives.

FRANCIS HARRINGTON

The CNA system of financial controls follows standard financial practice and, in addition, meets the requirements of pertinent federal regulations and contract provisions. These are the main features of CNA's financial system:

Budgets. Group Directors and Department Managers are provided with annual budgets and are responsible for performing assigned tasks within them. Expenditures are compared with budgets once a month; managers receive detailed reports for each contract in their individual groups or departments.

Cash Requirements. CNA's contract with the Navy provides access to working capital through an advance funding account. Advances are drawn weekly, on the basis of anticipated expenditures, and offset by monthly vouchers. Non-defense contracts are funded through progress payments; vouchers are processed once a month.

Reporting Systems. The CNA accounting system is designed for recording and reporting costs by project. Costs are reported on a fiscal year basis, with interim monthly reports.

Expenditure Review. All contract expenditures are reviewed by the Director of Finance and Administration and his staff. In FY 1980, about 72 percent of all expenditures (see page 52) went for staff salaries and related benefits. Expenditures for travel, supplies, equipment, and consultants are documented by requisitions and approved by CNA's management. Major purchases must be approved in advance by the Navy's Administrative Contracting Officer.

Audit Review. The CNA financial system is audited by the Defense Contract Audit Agency and the University's public accountant (Peat, Marwick, and Mitchell).

The following tables outline the financial status of CNA.

FUNDING IN FY 1980

(Thousands of dollars)

Source of funds

Defense:

CNO/CMC study program	\$11,483
Tactical Analysis Group	2,200
Other programs	<u>587</u>
Total defense	14,270

Non-defense:

Department of Labor	148
National Science Foundation	52
Other sponsors	<u>50</u>
Total non-defense	250

Total FY 1980 funds available	14,520
Funds carried forward from FY 1979	<u>(240)</u>
Total funds expended	<u>14,760</u>

Application of funds

CNA program costs	\$14,033
On-campus research	<u>727</u>
Total funds applied	<u>\$14,760</u>

STATEMENT OF COMPARATIVE FINANCIAL CONDITION
30 September 1980 and 30 September 1979

ASSETS

	1980	1979
Current assets		
Cash	\$ 189,710	\$ 269,565
Receivables (note 1)	163,130	194,755
Travel advances and prepaid items	346,591	230,462
Advances — U.S. Navy	<u>515,035</u>	<u>325,838</u>
Total current assets (note 2)	<u>\$1,214,466</u>	<u>\$1,020,620</u>

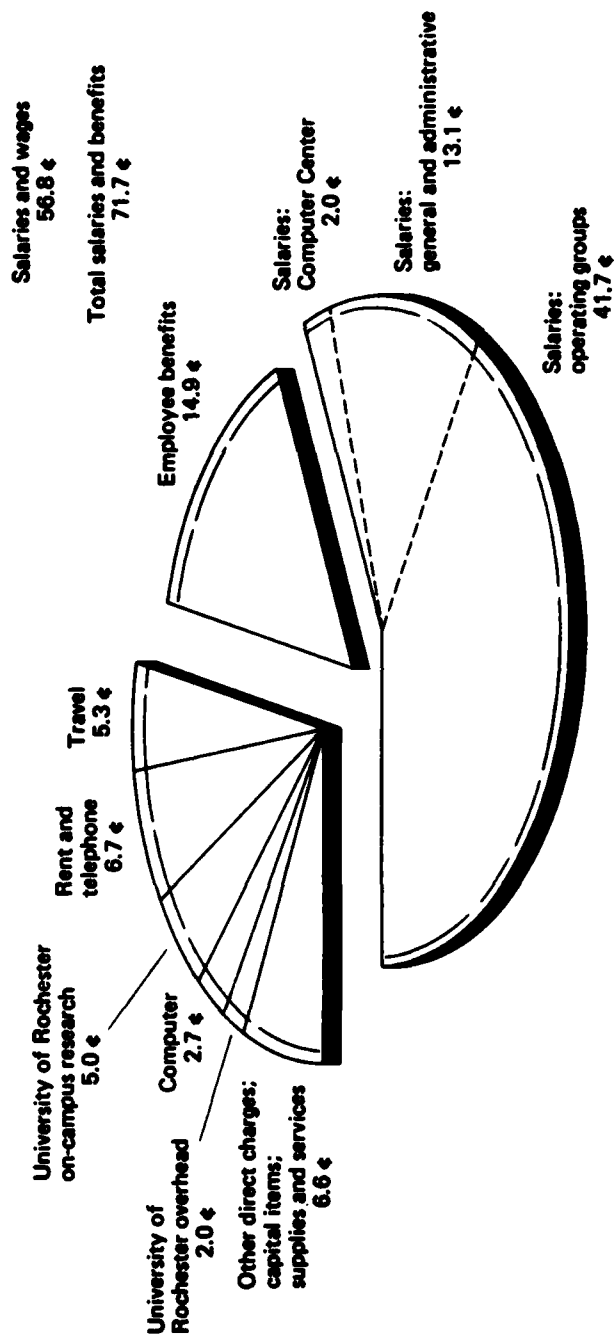
LIABILITIES AND RESERVE FOR DISALLOWANCES

Current liabilities		
Accounts payable \$ 417,337	420,079	\$ 194,660
Payroll taxes and other withholdings	<u>74,551</u>	<u>5,136</u>
Other liabilities		
Accrued annual leave	684,187	779,110
Unbilled labor adjustments	<u>35,649</u>	<u>41,714</u>
Total other liabilities	\$ 719,836	\$ 820,824
Total liabilities	<u>\$1,214,466</u>	<u>\$1,020,620</u>

NOTES:

1. Government agencies account for over 95 percent of all receivables.
2. CNA has no physical assets. Property and equipment constitute direct charges, with title vesting in the government.

APPLICATION OF THE RESEARCH DOLLAR IN FY 1980



VI. BOARD OF OVERSEERS

The Board of Overseers of the Center for Naval Analyses has the responsibility for formulating overall policy for CNA, maintaining high standards of professional competence and integrity in CNA's work, and reviewing the general management policies and personnel of the Center.

At three regular meetings a year, the Board reviews the work of CNA. At one of these meetings, held at the Center's offices, the methods and results of major research are presented in detail to the Board. Typically, about six projects, covering classified work done in the Washington area, are reviewed.

A second meeting is usually held near a CNA field office. This gives the Board an opportunity to review operational analyses done for the operating forces of the Navy and Marine Corps.

Unclassified research for Navy, Marine Corps, and non-defense sponsors is discussed with the Board at a meeting held at the University. The Board thus has the benefit of the views of University faculty members about the competence of CNA's work.

MEMBERS

W. Allen Wallis, Chairman of the Board
Chancellor and Honorary Trustee, University of Rochester

Martin J. Bailey, Professor of Economics, University of Maryland.
Former Assistant for Southeast Asia Forces, Department of Defense.

Andrew P. Borden, Executive Vice President of the Center for Naval Analyses. Former Chief Scientist, Systems Analysis Division, Office of the Chief of Naval Operations.

Kenneth E. Clark, Professor of Psychology and former Dean of the College of Arts and Sciences, University of Rochester. Member of the Army Science Advisory Board. Former consultant to the Office of Science and Technology.

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Adm. C. Donald Griffin, USN (Ret.), former Deputy Chief of Naval Operations. Former Commander in Chief, U.S. Naval Forces, Europe. Former Commander in Chief, Allied Forces, Southern Europe.

Donald K. Hess, Vice President for Campus Affairs, University of Rochester. Former Director, U.S. Peace Corps. Former Director for Program Management, Advanced Research Projects Agency.

Arthur Kantrowitz, Professor of Engineering and Senior Lecturer in Engineering Sciences, Dartmouth College. Former Chairman and Chief Executive Officer of Avco Everett Research Laboratory. Honorary Trustee of the University of Rochester.

David Kassing, President of the Center for Naval Analyses. Former Director of Research of the President's Commission on an All-Volunteer Armed Force. Former Director of Naval Forces Division, Office of the Assistant Secretary of Defense (Systems Analysis).

William H. Meckling, Dean of the Graduate School of Management, University of Rochester. Former member of the National Science Board. Former Executive Director of the President's Commission on an All-Volunteer Armed Force. Former President of the Center for Naval Analyses.

Elliot W. Montroll, Albert Einstein Professor of Physics, University of Rochester, and Director of the Institute for Fundamental Studies. Former Vice President, Institute for Defense Analyses.

William A. Nierenberg, Director of the Scripps Institution of Oceanography.

Frank P. Sanders, Vice President of the Signal Companies, Inc. Former Under Secretary of the Navy.

Robert L. Sproull, President and Chief Executive Officer of the University of Rochester. Trustee of the University of Rochester. Former Chairman, Defense Science Board. Former Director, Advanced Research Projects Agency.

Brian J. Thompson, Dean of the College of Engineering and Applied Science, University of Rochester. Former Director of the Institute of Optics, University of Rochester.

LaRoy B. Thompson, Senior Vice President and Treasurer of the University of Rochester. Member (and former Chairman) of the Board of Associated Universities.

Adm. W. F. A. Wendt, USN (Ret.), former Deputy Chief of Naval Operations. Former Commander in Chief, U.S. Naval Forces, Europe.

Albert Wohlstetter, Senior Fellow of the Hoover Institution, Stanford University. Former member of the professional staff and Research Council, the Rand Corporation.

Clarence L. A. Wynd, former Vice President and Director, the Eastman Kodak Company. Honorary Trustee of the University of Rochester.

PAST MEMBERS

Carl Amthor (1969-72)

Charles J. DiBona (1967-73)

McCrea Hazlett (1967-71)

Hubert Heffner* (1973-75)

Robert Loewy (1967-74)

Stephen Lukasik (1975-77)

David A. McBride (1967-78)

Russell Murray 2nd (1974-77)

Patrick Parker (1967-72)

**Deceased*

LEND

DATE
FILMED

4-81

DTIC